Functional Performance Test

Variable Frequency Drive (VFD)
VAV Fan Application

Constant Static Pressure Application

Project: _____ Date: _____
Address: _____

Commissioning Participants:
Commissioning agent: _____ of _____
EMS operator: _____ of _____
VFD technician: _____ of _____
HVAC technician: _____ of _____
Owner's rep.: _____ of _____

Air handler ID:_____. ___ Supply fan (SF) Hp: ___ CFM: _____ RPM _____ SP_____
___ Return fan (RF) Hp: ___ CFM: _____ RPM _____ SP_____
VFD brand and model: _____

The following functional performance test is for a VFD controlling a VAV air handler to a **constant** duct static pressure (SP). *A check-mark denotes acceptance or compliance.*

I. Design Intent and Documentation Verification

___ Review the design documents and the specifications.
___ Verify that the VFD ___description, ___specifications, ___technical and troubleshooting guide and the installation, ___programming record and ___balance report are on-site.
From the design documents determine: Location of static pressure sensor:
_____
Nearest duct fitting upstream (fitting and distance):_____
Nearest duct fitting downstream:_____
Control strategy for the return fan:_____
_____

II. VFD Installation

Static Pressure Sensor

Linear Position

Location of sensor in % of the distance from fan to terminal box: _____
Normally, the sensor should be located 2/3 to 3/4 the distance from the fan to the terminal box of the most restrictive branch.

____Complies?

Pressure Reading Reliability

Nearest duct fitting upstream (fitting and distance):_____
Nearest duct fitting downstream:_____

The SP sensor controlling the VFD must be located so as to properly sense the static pressure in the duct without being adversely affected by changes in flow from duct fittings. This ideally requires the sensor to be at least 10 duct diameters downstream and 5 duct diameters upstream from any duct takeoff or elbow fittings.

___Complies?

Pressure Offset (Po)

Duct static pressure fan is being controlled to: _____in. H_20 [A].

Pressure rise across supply fan at design conditions (from balance report summary): _____in. H_20 [B]. Pressure offset, Po, [A] / [B]: _____.

Optimally, Po should be 0.3 or less in order for the VFD and fan to be able to respond to small pressure changes and realize adequate energy savings. If Po is greater than 0.4, the duct SP sensor is probably located too close to the fan.

___Complies?

Balancing to Lowest Pressure

Review the HVAC balance report and verify that according to the report, the system was balanced so the VFD controls to the lowest possible duct static pressure (that is, a capacity test was performed). The controlling duct static pressure from balance reports is _____in. H_20. The corresponding VFD frequency or fan RPM from the balance report is: supply fan (SF):_____, return fan (RF):_____. Refer to the end of this test for details of the capacity test.

___Balanced to lowest static? (this is further verified by #2 under Section IV)

Turn-Down Ratio

What is the minimum Hz the VFD will take the fan to? _____ What is the reason for any limitations?_____

General Issues

___ Verify that any power quality mitigation measures required from the specifications have been completed.

___ Verify that any inlet vanes or outlet dampers on the fan have been removed or permanently held full open.

___ Verify verbally that the acceleration and deceleration ramp time of the VFD is between one and four minutes.
Actual ramp time: up _____min. down _____min. (too short of ramp times will result in "hunting" and excess modulation by the VFD, typical ramp times are 1 to 4 minutes)

___ Verify that the lower frequency limit is 0, unless explained.

___ Verify that the VFD has been integrated into the EMS as per specification.

___ Verify that the EMS monitors the duct static pressure or that an in-line "T" in the static pressure hose is extended to near the VFD, from which a magnehelic static pressure reading can be made during testing.

III. Functional Performance Test

This test is not intended to verify that the VAV system is functioning properly, but rather that the VFD is functioning properly.

1. **Boxes Partially Open (intermediate CFM).** If current conditions are such, that the system is not expected to be in full cooling, nor be at the minimum flow condition:
   a. Read the frequency output of the VFDs and record in Table 1 in the "Boxes Partially Open" column for both the supply fan (SF) and return fan (RF) if applicable.
   b. Read the duct static pressure and record in the same column.

   If the conditions are not in an "intermediate" position, change all space temperature set points to 4 degrees below the actual temperature in the space, to simulate an approaching of thermostat satisfaction and take readings.

2. **Boxes to Maximum Open (Full Cooling).** Using the (EMS) or other means, change all the space temperature setpoints to at least 10 degrees below the current space temperature so that the entire HVAC system supplied from this fan is in full cooling in all zones and *all* terminal boxes are open to their maximum "stops."

   a. Measure or read the duct static pressure controlling the VFD and record in the "Open to Max. Stop" column in Table 1.
   b. Read the frequency output of the VFDs and record in Table 1.

3. **Boxes to Minimum Positions.** Change all space temperature set points to be equal to the actual space temperatures to simulate a satisfied condition, driving the boxes to their minimum.
   a. Take the frequency and static pressure readings and record in Column D.

IV. Analysis

Table 1.

A Design static pressure_____ Design freq. (Hz): SF _____ RF _____ Design RPM: SF_____ RF _____ SP being contolled to now _____	**B** **Terminal Boxes Open to Max. Stop**	**C** **Boxes Partially Open**	**D** **Boxes Closed to Min. Stop**
	SF | RF	**SF | RF**	**SF | RF**
VFD frequency. or RPM	|	|	|
Static pressure during VFD test			
Static pressure during capacity test		(from TAB report data form)	

1. Fractional variance of SF design frequency or RPM to full open, 1-(B / A): _____. If the full open SF frequency or RPM is more than 5% less than the design value (assuming the design and actual static are equal), all boxes may not be driven full open. Investigate as appropriate.
___Less than 5% variance?

2. The SP with full open boxes (B) should be significantly less than the SP during the partially loaded conditions and should be within 0.15 inches SP of the SP from the capacity test. If

the VFD SP is greater than the capacity test SP, all boxes may not be fully open. If the SP's are not close to each other, the TAB data may be innaccurate. Compliance basically verifies that a capacity test was completed.

___Complies?

3.___**Is the SP in (C) and (D) within 10% of the what it's being controlled to in (A)?**

4.___**The min. turn down ratio (from Section II) should be close to (freq. D/B) Y/N?**

5.___**Return fan RPMs or frequencies track well with changes in SF RPM, accounting for changes in OSA quantities and relief strategy?**

6. Static pressure (SP) readings at the last two conditions should remain within 5% of each other. If the there is more than a 5% variance, the sensor may be unstable, possibly from being too close to duct fittings.

___Less than 5% variance?

___**Collaborative Trending:** If the variance is greater than 5% and if the Pressure Reading Reliability location doesn't comply, from Section III, trending (monitoring) the SP against terminal unit damper position or SF flow is recommended to confidently verify stability. The SP should remain constant (+/- 5%) regardless of damper position or flow.. SP trended? _____

___Complies? (sensor is stable)

7.___**For the frequency or RPM readings in Table 1, are the values in Col. B > C > D?**

V. Training

___The training specified in the design incentive agreement has been completed.

Required Capacity Test

To insure that energy use is minimized, the HVAC system must be balanced at design conditions at the lowest possible static pressure possible. This requires that the lowest possible static pressure (SP) be found at the sensor that will allow full design flow at the TU most difficult to satisfy. This system minimum SP found is what the VFD should control to. This is accomplished by changing the temperature setpoint for all zones to 55F, causing all terminal units (TU) to be calling for full cooling. Each TU's airflow is then measured against the design flow. The TU that is receiving the lowest fraction of design is identified. The current SP at the controlling sensor is noted. A calculation is made, giving the SP required at the sensor to allow the identified most critical TU box to meet its design flow. The equation is $SP_2 = SP_1 \times Q_2^2 / Q_1^2$. Where Q_1 = actual or fraction of design flow during capacity test. Q_2 = design flow or 1.0 if using fractions. SP_1 = SP at sensor. SP_2 = SP to control to. It is noted that if all boxes were calling for full cooling simultaneously, the fan could not maintain the new SP_2 value, due to diversity fan size reduction having been made by the design engineer.

Parties required for VFD site commissioning work

Commissioning agent To witness and record the tests.
EMS operator To drive boxes open and shut by changing the set points, etc.
VFD technician To use the keypad to verify the ramp time. (unless verified at start-up, which is recommended). Sequencing the keypad to display ramp time could be done by the commissioning agent, alone after reviewing the VFD technical manual.
HVAC technician To apply magnehelic gages to the pressure tap to measure duct static, if not monitored by EMS.